Optically pumped GaAs surface laser with corrugation feedback*

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A GaAs distributed-feedback laser was fabricated and pumped optically. A narrow stimulated spectrum was obtained around 0.83 μ with threshold pumping power of $\sim 2\times 10^5$ W/cm^2.

Among the promising materials for integrated optical circuit applications are GaAs and its alloys.[1] The ability to perform basic functions such as guiding, switching,[2] coupling,[3] and detection[4] in thin guiding layers of this material has recently been demonstrated. In this letter, we report on a GaAs surface laser with corrugation feedback. This configuration, applied for the first time to a semiconductor laser, is of interest because of the inherently different form of spectral and modal control which it affords[5,6] in comparison to conventional reflecting mirrors. The freedom from the use of polished end reflectors facilitates the coupling of such a laser to other monolithic circuit components.

In our experiment the feedback was provided by a periodic corrugation of the GaAs-air interface which Bragg couples the forward and backward travelling waves of the laser. The use of corrugation feedback with a dye laser was previously described by Zory.[7]

A schematic drawing of the laser is shown in Fig. 1. The GaAs wafer was n type (Si doped) with a carrier concentration of 10^{18} cm^{-3}. The top surface was polished and chemically etched. The corrugation was produced by ion milling through a photoresist mask generated by holographic photolithography.[8]

The Bragg feedback condition is

$$2\beta = m2\pi/\Lambda, \quad m = 1, 2, \ldots \tag{1}$$

where β is the propagation constant of the guided mode and Λ is the period of the corrugation. The use of first-order coupling due to the fundamental Fourier component ($m=1$) of the corrugation function requires a period of $\Lambda \simeq \lambda_0/2n \simeq 0.12\ \mu$ in GaAs. In this experiment coupling was provided by the third Fourier component of the corrugation function, so that the period was $\Lambda \approx 0.35\ \mu$. As a consequence, the lower Fourier components couple to the substrate radiation modes and thus present a loss mechanism to the laser mode.

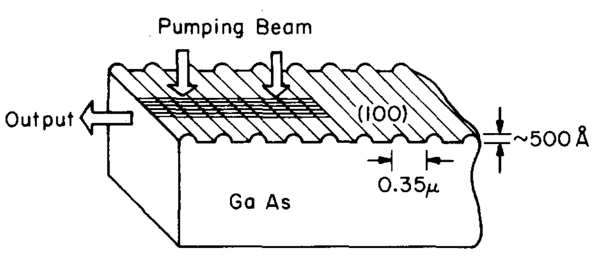

FIG. 1. Schematic structure of a GaAs distributed-feedback laser.

Gain was provided by optical pumping using a Q-switched ruby laser ($\lambda_0 = 0.6943\ \mu$). An individual pumping pulse had a duration of ~20 ns, and the peak power was attenuated down to ~10 kW. A cylindrical lens was used to pump a rectangular strip of 3×0.5 mm. The threshold at liquid-nitrogen temperature was approximately 2×10^5 W/cm^2. The output beam emerged through a lapped face. The opposite face was left unpolished and was not parallel to the output face so as to minimize reflection feedback.

A typical emission spectrum of a sample excited above threshold is shown in Fig. 2. Stimulated emission is indicated by the narrow resolution-limited peak. The spectrum of a sample without corrugation is also shown under the same pumping conditions, displaying only the broad (~180-Å) spontaneous-emission features. The induced-emission spectrum is peaked at $\lambda_0 = 0.832\ \mu$,

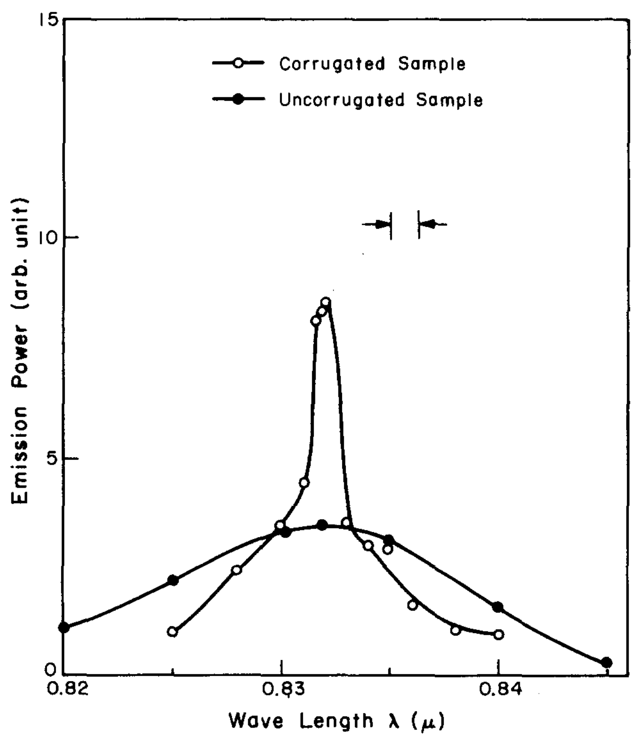

FIG. 2. Emission spectrum of a corrugated and an uncorrugated sample. Pumping intensity is 5×10^5 W/cm^2.

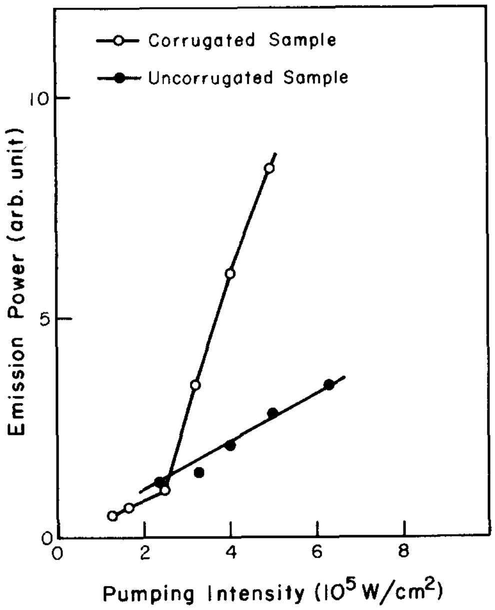

FIG. 3. Emission power as a function of pumping intensity; $\lambda = 0.832\ \mu$.

which by using Eq. (1) corresponds to an index of refraction $n = 3.6$ at 77 °K.

Figure 3 shows plots of the emission power as a function of the pumping intensity for a corrugated and an uncorrugated sample. The "break" in the curve of the corrugated sample near 2.5×10^5 W/cm^2 coincides well with the first appearance of the narrow spectral peak in Fig. 2. The characteristics of the uncorrugated sample, however, remain linear up to the highest pumping power employed.

We can account fairly successfully for the observed threshold power by taking into account the absorption in GaAs as well as the loss to the substrate. The use of a thin epitaxial layer and of first-order coupling due to the fundamental Fourier component is expected to lead to a large lowering of the threshold so that electrical pumping will be feasible. Work along this direction is in progress.

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